# Antiproton Working Group Summary

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(written contribution coauthored by Mark Mandelkern, UCI)

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# Context - 1

- The antiproton source is fully employed, and is likely to remain fully employed as long as the Tevatron Collider is running.
- Antiproton source performance will not be dramatically changed by proton driver.
  - Proton Driver = x2 in pbar stacking rate (smaller than improvement still planned for Run II).

# Context - 2

- The antiproton source is nearly unique in the world.
  - CERN AD is the only currently running program (3 experiments with stopping pbars)
  - Antiprotons play a central role in the planned GSI upgrade (FAIR = Facility for Antiproton and Ion Research).

# Topics Considered

- Quarkonium formation experiments.
- $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$ (search for CP violation).
- ~~Light hadron spectroscopy.~~
- ~~Experiments with stopping $\bar{p}$.~~
- Debuncher ring as a prototype $\nu$-factory.

# Quarkonium Formation

- Advantages of $\bar{p}p$ over $e^+e^-$:
  - All quantum numbers are directly accessible (not just $1^{--}$).
  - No synchrotron radiation → very small beam energy spread is possible (w/cooling) → best possible heavy quarkonium mass and width measurements.

# Charmonium

- Goals:
  - $h_c$ confirmation, $\eta_c$' mass discrepancy, widths of both.
  - Other expected narrow states identified and characterized
    - $1^1D_2$, $1^3D_2$, $1^3D_3$, $2^3P_2$, $1^1F_4$.
  - Could be done in the Accumulator with a gas jet target (like E760, 835)
  - Part of the program planned for GSI.

# Bottomonium

- Many states are not yet observed
  - Singlet 1S, 2S, 1P, and 2P.
  - D states.
- P state widths not yet measured.
- Feasibility of experiment depends on production cross section.
  - Not yet known; calculable given bottomonium branching ratio to $\bar{p}p$.
  - CLEO has enough data to measure the brancing ratio or prove it too low.

# Bottomonium, continued

- Experiment makes sense if branching fraction to $\bar{p}p$ is $\sim 10^{-4}$, and luminosity of $\sim 10^{32}$ $cm^{-1}sec^{-1}$ is possible.
- Gas jet experiment would require a new ~50 GeV ring & luminosity would be hard to achieve.
- Very high intensity ~5x5 $\bar{p}p$ colliding beam machine might be possible in the Booster tunnel!
- The CLEO III detector might be perfect and might be available!

# CP Violation in hyperon decays

- P859 (1992) proposed $\bar{p}p \rightarrow \bar{\Lambda}\Lambda$
  - Hydrogen gas jet target & new low energy storage ring with cooling.
- HyperCP will come close to sensitivity proposed by P859.
  - Possible to get enough statistics to improve another order of magnitude (x100 in events).
  - No study of systematics.

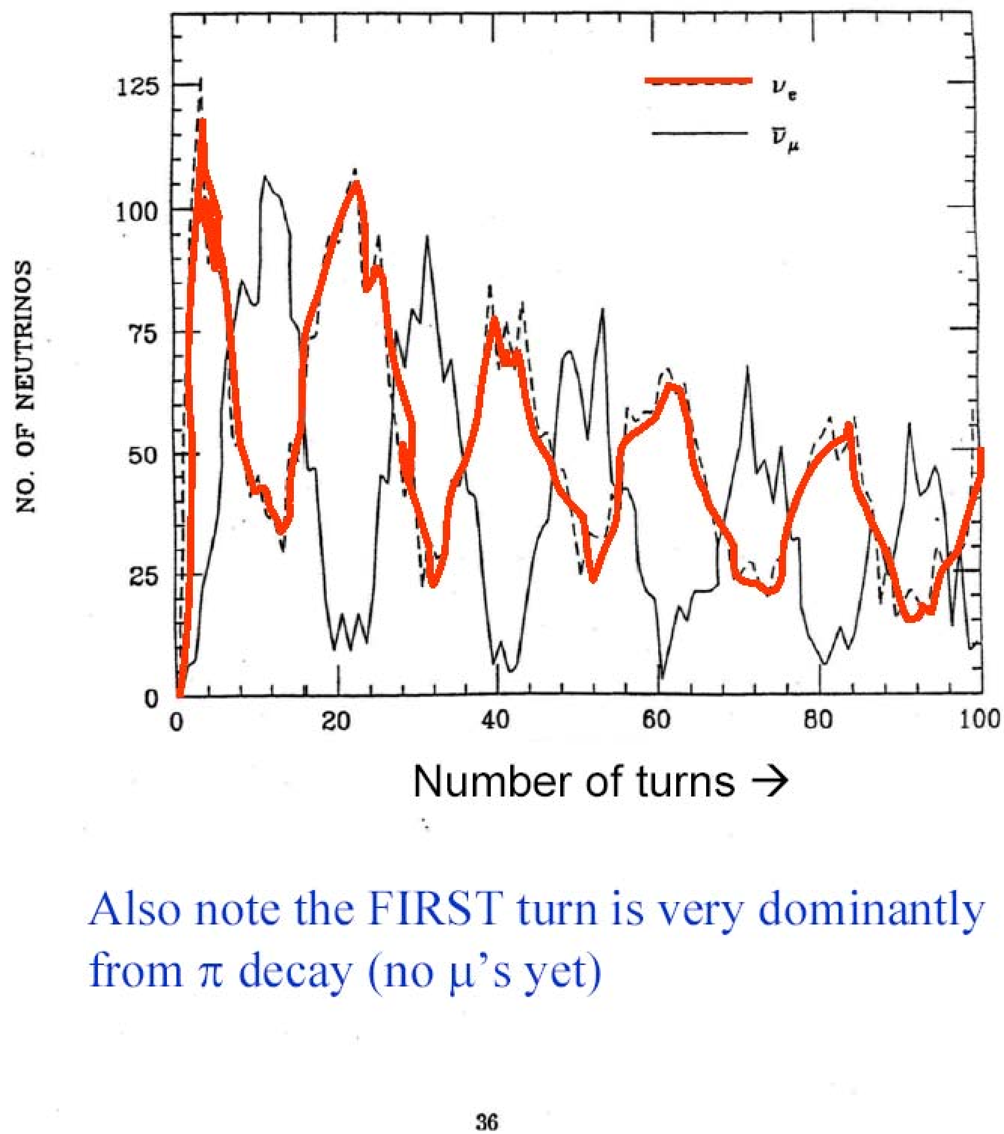
# Prototype Neutrino Factory

- In normal operation of the $\bar{p}$ source, $\pi$'s as well as $\bar{p}$'s are captured by the Debuncher.
  - Yields prompt $\bar{\nu}_\mu$'s from $\pi^- \rightarrow \mu^- \bar{\nu}_\mu$ .
  - Delayed $\bar{\nu}_e$ and $\nu_\mu$ from $\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$.
- This has been pointed out before.
  - P860
  - "Test beam" proposal by John Cooper.

(From John Cooper)

# *Actually get "Tagged"* $\nu_\mu$ *and* $\overline{\nu_e}$

- Muons captured in the Debuncher have to be within +- 2% of the momentum aperture, so only forward decays survive. V-A means that the muons are polarized
- Muon spin precesses in the magnetic field
  - Spin precession period ~ 20 turns
  - So there is a time separation of $\nu_\mu$ and $\overline{\nu_e}$
- **THIS BEGINS TO LOOK LIKE A TEST BEAM !**




Number of turns →

Also note the FIRST turn is very dominantly from π decay (no μ's yet)

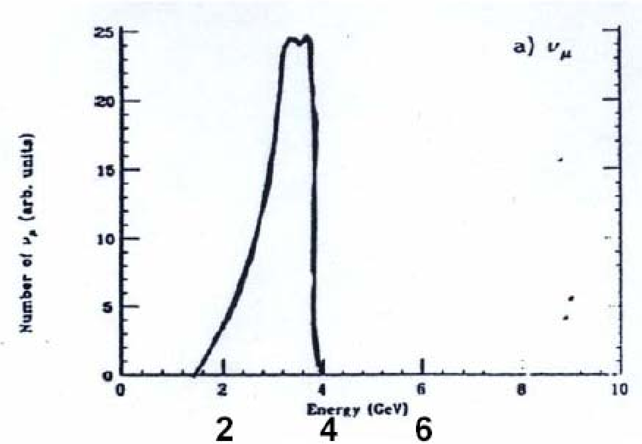
(From John Cooper)

# *Debuncher Neutrino Energy Spectra*

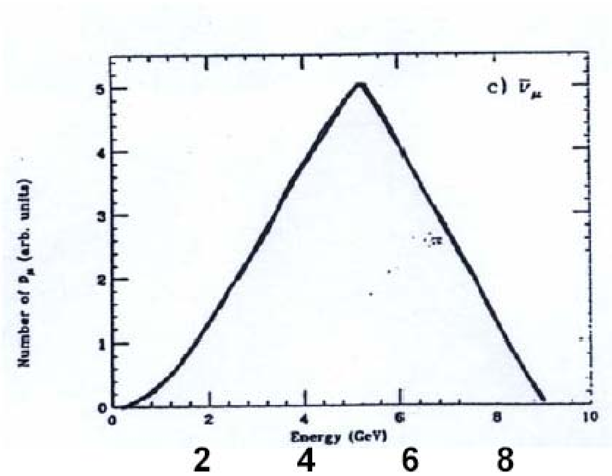
**for +- 10 mrad cone forward**

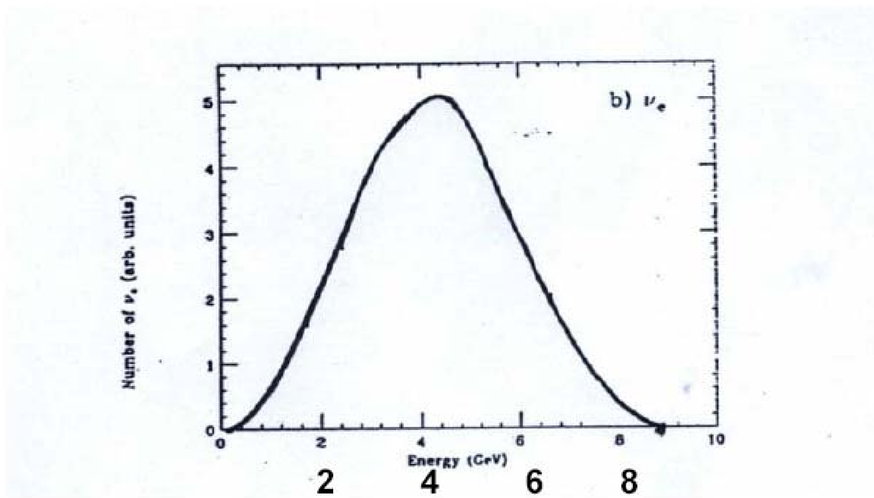
- Get 20 π's for every pbar produced

This is a two body decay, so angle & Energy are correlated at your prototype detector, giving a handle on the Neutral Currents




- Get 1 μ for every pbar produced



# Prototype Neutrino Factory - 2

- If the antiproton source were not needed for making antiprotons…
  - Debuncher could collect 8 GeV positives.
  - Debuncher could operate at lower energy with either polarity.
    - Could collect pions made by MI protons with energy less than 120 GeV.
    - Could collect pions made by 8 GeV protons.
    - Could store muons prepared by a prototype muon source.

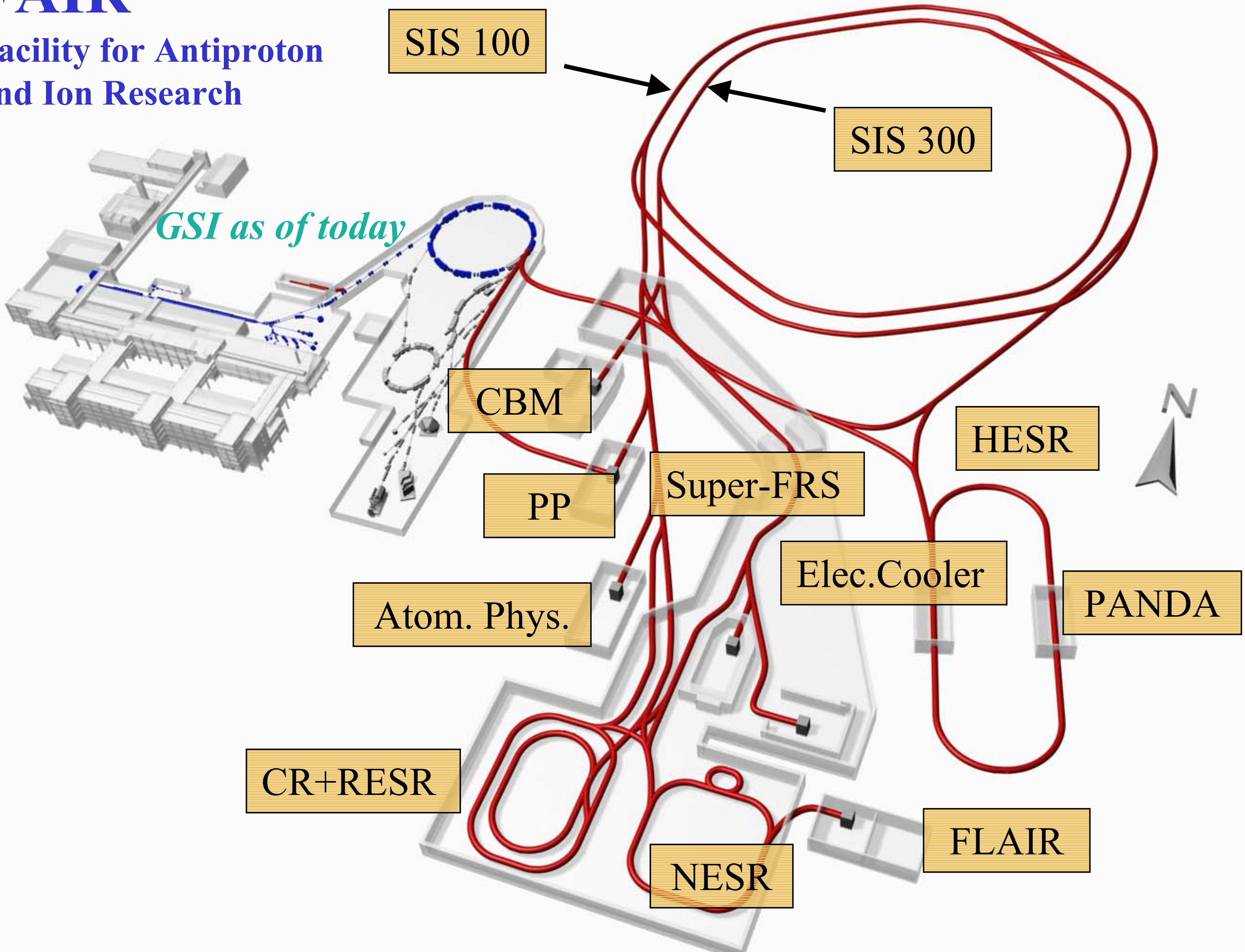
The End.

# Backup Slides

# FAIR

**Facility for Antiproton and Ion Research**

Red = New



# GSI Planned Antiproton Physics Program

- Charmonium Spectroscopy. Precision measurement of masses, widths and branching ratios of all ($c\bar{c}$) states (hydrogen atom of QCD).
- Search for gluonic excitations (hybrids, glueballs) in the charmonium mass range (3-5 GeV/$c^2$).
- Search for modifications of meson properties in the nuclear medium, and their possible relation to the partial restoration of chiral symmetry for light quarks.
- Precision $\gamma$-ray spectroscopy of single and double hypernuclei, to extract information on their structure and on the hyperon-nucleon and hyperon-hyperon interaction.

(from Diego Bettoni)